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THE WHOLE PICTURE: BODY POSTURE RECOGNITION IN INFANCY

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THESIS

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ABSTRACT OF THESIS

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Holistic image processing is tied to expertise and is characteristic of face and body processing by adults. Infants process faces holistically, but it is unknown whether infants process body information holistically. In the present study, we examined whether infants discriminate changes in body posture holistically. Body posture is an important nonverbal cue that signals emotion, intention, and goals of others even from a distance. In the current study, infants were tested for discrimination between body postures that differ in limb orientations in three conditions: in the context of the whole body, with just the limbs that change orientation, or with the limbs in the context of scrambled body parts. Nine-month olds discriminated between whole body postures, but failed in the isolated parts and scrambled body conditions, indicating that they use holistic processes to discriminate body information. In contrast, 3.5-month olds failed to discriminate between whole body postures, therefore no conclusion can be drawn about their ability to process bodies holistically. These results indicate that infants process body information holistically during the first year of life, but there are developmental changes in the processing of body information from 3.5 to 9 months of age.

KEYWORDS: Infant Development, Holistic Processing, Body Representation, Visual Perception, Body Posture

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter One:

Introduction

The human visual system applies a specialized perceptual process to encode faces. The development of this system is facilitated by an instinctive tendency to attend to faces early in life and subsequent repeated exposure to faces (Carey, De Schonen & Ellis, 1992; Diamond & Carey, 1986; Leder & Bruce, 2000; Maurer, Le Grand & Mondloch, 2002; Morton & Johnson, 1991). More recently, researchers have learned that adults apply a comparable specialized strategy to process information from bodies (Reed, McGoldrick, Shackelford & Fidopiastis, 2004; Reed, Stone, Bozova & Tanaka, 2003; Reed, Stone, Grubb & McGoldrick, 2006). However, not much is known about the development of body knowledge. This is in contrast to an abundance of research on the development of face processing. The goal of the current research is to address this gap in the literature. Specifically, we used the part-whole procedure developed by Tanaka and Farah (1993) to examine whether infants (a) discriminate between body postures and (b) employ a holistic strategy to process this body information.

Processing of Social Stimuli

We open with a brief review of the research on body processing and its relation to research on face processing. The most noticeable similarity between bodies and faces is that one's cumulative experience with faces is likely the same as that with bodies. Research shows that this collective experience leads to a level of expertise in adults that allows for the recognition of countless individuals and the extraction of social information (for reviews see Lee, Anzures, Quinn, Pascalis & Slater, 2011; McKone, Crookes, Jeffery & Dilks, 2012). Adults can quickly and accurately detect information about gender, emotional state, identity, and intention from bodies even in cases when facial information is not available (Atkinson, Dittrich, Gemmell & Young, 2004; Reed et al., 2007; Walk & Walters, 1988; Walters & Walk, 1986). In fact, body posture alone can allow one to recognize the nature and intensity of emotions (Coulson, 2004). Additionally, body information may be utilized before face information for identification in certain circumstances (i.e., viewing someone at a distance). Moreover, researchers propose that the face and body are subcomponents of a larger perceptual person unit. This seems likely because the visual system rarely encounters isolated faces or bodies in natural conditions (McArthur & Baron, 1983; Russell, 1997). Consequently, faces and bodies are likely to be processed similarly.

A second commonality between bodies and faces is they share many structural properties. For example, faces and bodies both have identifiable parts located in particular configurations. In faces, the typical arrangement of parts consists of two eyes above the nose, which is above the mouth. Similarly, body parts (i.e., head, torso, legs, and arms) are constrained to a prototypical arrangement (head above torso, legs below torso, arms extending from torso), with the relative shape and size of these parts providing detailed information for recognition and identification of specific bodies (Reed et al., 2006; Seitz, 2002).

Additionally, neurological research suggests a strong link between faces and bodies as evidenced by the proximity of brain regions associated with face and body perception—the location of the extrastriate body area and the fusiform body area are very close to the occipital face area and the fusiform face area (Atkinson, Vuong & Smithson, 2012; Kanwisher, 2010; Orlov, Makin & Zohary, 2010; Peelen, Glaser, Vuilleumier &

Eliez, 2009). However, there is some dissension about how this neuroimaging data should be interpreted (e.g., Weiner & Grill-Spector, 2012; Xu, 2005). Event-Related Potential (ERP) studies provide additional support for the claim that adults display specialized processing of bodies, as they do for faces. When adults view human bodies, there is evidence of an enhanced negative event-related potential, the N190. The N190 is not exhibited when viewing scrambled bodies (Thierry et al., 2006).

One final parallel between faces and bodies lies in the internal personal experiences one has with both faces and bodies. The perception of faces and bodies is integrated with the subjective experience of using a face or body, a quality which has been termed “embodiment” (Gallese & Goldman, 1998; Reed et al., 2006). Embodiment refers to the fact that the recognition of another person’s actions is affected by experience with one’s own body and facial movements. It is thought that this experience leads to a superior ability to extract detailed information about the human face and body (Kontra, Goldin-Meadow & Beilock, 2012).

Processing Faces and Bodies as “Special” Objects

Given that faces and bodies share several functional and structural commonalities, one way to investigate human body knowledge is to compare the representation and processing of the two types of stimuli. Although less research has been conducted with bodies than with faces, studies completed with adult subjects indicate many parallels between expertise in face and body processing (Gliga & Dehaene-Lambertz, 2005; Minnebusch & Daum, 2009; Reed et al., 2003, 2006; Slaughter, Heron-Delaney & Christie, 2012). Adults use three types of information to process faces. The first type is featural information. Featural information refers to discrete, commonly identified parts of the face such as the eyes or nose. The second type of information, configural information, refers to both the first-order relations (the gross structural information, such as the fact that the nose is located above mouth), and second-order relations (the fine spatial relations among features, such as the distance between the eyes). Finally, expert processors often perceive the object or face as a whole unit rather than a collection of independent features—holistic information (Maurer et al., 2002).

A considerable amount of evidence from behavioral and neuroimaging studies suggest that humans perceive faces differently than other objects because faces are processed more holistically (see Kanwisher & Dilks, 2012, for a review). Holistic information refers to a specific type of relational processing in which the features of a face are not represented as separate parts but as an overall wholistic template (Bartlett & Searcy, 1993; Diamond & Carey, 1986; Farah, Tanaka & Drain, 1995; Tanaka & Farah, 1993). Moreover, the wholeness of a face, or its configural completeness, hinders accurate recognition of individual features or parts (Fifić & Townsend, 2010). Researchers have constructed a featural-to-holistic processing continuum (Carey et al., 1992; Diamond & Carey, 1986; Leder & Bruce, 2000; Reed et al., 2006; Tanaka & Farah, 1993) in which objects, such as houses, are at the recognition-by-features end of the continuum, while faces are at the holistic end. One aim of the current study is to investigate where bodies lie on this continuum for infants.

Tanaka and Farah (1993) demonstrated the holistic nature of face processing through a series of experiments examining the influence of configural transformations on recognition of individual features. They used a forced-choice recognition task of individual features of faces (e.g. identify Jim’s nose). This methodology is often referred to as the part-whole paradigm. Recognition of face parts was measured under two conditions. In one condition, the parts were presented in the context of the whole face; in the other condition, the parts were presented in isolation. Adult participants were less accurate at identifying isolated parts than identifying them in the context of whole faces (Tanaka & Farah, 1993). On the other hand, accuracy of identifying parts of scrambled faces and houses was the same in the isolated part and whole stimulus conditions. These results led Tanaka and Farah (1993) to conclude that faces are typically processed holistically, while scrambled faces and houses are typically processed featurally. Thus, the part-whole paradigm examines the processing of parts individually and in the context of the whole face, and superior performance in the latter condition is taken to imply holistic processing (Farah et al., 1995; Farah, Wilson, Drain & Tanaka, 1998; Fifie & Townsend, 2010; Tanaka & Farah, 2003). Again, holistic processing is considered a mark of expert processing in adults that is applied to faces and to bodies.

There are two ways in which studies on adults have investigated the holistic processing of body stimuli. The first involves the holistic processing of bodies themselves (i.e., sans faces). Reed and colleagues (2003) presented adult participants with pictures of human body postures and used the same/different paradigm to test memory for the original body posture. When the body to be judged was inverted or scrambled, matching performance was impaired compared to performance on upright body postures. Because such inversion effects in face processing have been associated with holistic processing of upright but not inverted stimuli, poorer performance on inverted body stimuli was taken to indicate holistic processing of upright bodies.

The second type of procedure to investigate holistic processing involved a more direct approach by Reed and colleagues (2006), who examined the specific type of information adults use to process body information (i.e., featural, configural, holistic) by manipulating the type of stimulus information. First, they compared recognition on upright versus inverted isolated body parts (i.e., a single arm, leg or head). When the isolated body parts were inverted, matching performance was not significantly different on upright and inverted stimuli; however, there was evidence of an inversion effect for whole bodies. Again, poorer performance on inverted body stimuli was taken to indicate holistic processing. Thus, local part information was not enough to elicit specialized holistic processing for these body parts. Similarly, no inversion effects were found for scrambled body stimuli. Thus, the presence of all body parts does not elicit holistic processing; rather, the parts must be attached to form an intact, whole body. Researchers interpreted these results to suggest that the specific spatial relations among parts are critical for processing body posture information.

Additionally, researchers have employed the Tanaka and Farah (1993) part-whole paradigm to examine the holistic nature of body processing. For example, McGoldrick (2003) (as cited in Reed et al., 2006) had adult participants learn to associate specific names with specific body images (e.g., Joe or Bob). Then, he asked participants to recognize individual body parts either in the context of the whole body or in isolation (e.g., Which is Bob's arm? Which is Joe's leg?). Adults recognized individual body parts more accurately in the context of the whole body than when presented by themselves. Seitz (2002) also used the part-whole paradigm to investigate face and body recognition in children and adults. Adults, as well as 8- and 10-year-old children, recognized parts more accurately when presented in the context of the whole face or whole body than when presented in isolation. Seitz concluded that whole person recognition relies on similar holistic processes as face recognition in both children and adults. Thus, body processing in general and gesture processing in particular is holistic in adulthood and early childhood. To our knowledge, this issue has not been addressed previously in infancy. The goal of the current study is to examine the development of holistic processing of body posture in infancy.

The Development of Holistic Face Processing

Numerous researchers, with diverse stimuli and multiple populations, have used the logic of the part-whole paradigm to examine the development of holistic processing of faces. For example, Tanaka and colleagues (1998) found that, like adults, 6-year-old children showed a whole-over-part advantage in face processing. Pellicano, Rhodes, and Peters (2006) replicated these results with even younger children, 4-year olds.

Furthermore, a collection of studies by Cohen and Cashon (2001, 2004) indicates that a complex set of changes takes place in face processing during the first year of development. At 3 months of age infants looked equally often to familiar and composite faces (i.e., images composed of parts from different faces), leading researchers to conclude that they are processing the independent features of faces. Four-month-old infants integrated featural information to form a whole, whereas 6-month-olds appeared to regress back to featural processing. Finally, at 7 months, infants responded to the relations among features for upright but not inverted faces, much like older children and adults. These findings are consistent with the concept of infant perception as a constructive process in which infants initially process information as independent features and then later integrate the features into larger wholes (Cashon & Cohen, 2004;

Cohen & Cashon, 2001; Cohen, Chaput & Cashon, 2002).

Yet another methodology used to examine the holistic processing of faces is the Thatcher Illusion. The Thatcher Illusion refers to the idea that one is able to discriminate inverted features (e.g., eyes and mouth) in an upright face but fails to discriminate the same changes in an inverted face (Thompson, 1980). The inversion of features is thought to affect configural information and the changes are more easily detected in upright faces but not in inverted faces. In Bertin and Bhatt (2004), infants discriminated between normal and thatcherized faces when they were upright but not when they were inverted. These results demonstrated that infants experience the Thatcher Illusion, thereby indicating that they process relational information in faces.

In another study, Bhatt, Bertin, Hayden and Reed (2005) habituated 3- and 5-month-olds to schematic line drawings of undistorted female faces. At test, they were presented with two faces: one with a normal configuration, and the other with modifications to its configural information. Five-month-old infants discriminated between normal and configurally distorted faces but 3-month-olds did not, thereby demonstrating once again that configural face processing develops sometime between 3 and 5 months of age. Furthermore, Hayden, Bhatt, Reed, Corbly and Joseph (2007), presented 5- and 6.5-month-old infants with normal and configurally altered photographs of real faces with distortions to their configural information confined to normal ranges found in the population (Farkas, 1994). The results indicated that both 5- and 6.5-month old infants were able to discriminate between the faces (Hayden et al., 2007). Taken together, this research suggests that 3-month-old infants lack the ability to discriminate among faces using relational information, but 5-month-olds and older infants are able to use the relations among features to discriminate between faces.

In contrast, Quinn and Tanaka (2009) claimed that 3- to 4-month-olds are, in fact, sensitive to relational changes. Infants were familiarized to relationally distorted photographs of faces. The relational information was manipulated such that either the distance between the eyes or the distance between the nose and mouth was changed. Quinn and Tanaka found that 3- to 4-month-olds are sensitive to these changes. It is possible, however, that the infants in this study discriminated because the relational changes resulted in unnatural faces that were outside of physiognomic norms. Thus, the relational changes were of greater magnitude than those made by Hayden and colleagues (2007). However, this study shows that 3-to-4-month olds are able to process relational information in faces if the relational changes are large. Altogether, these studies indicate that infants begin to process faces in a holistic manner quite early in life.

The Development of Body Processing in Infancy

While, as discussed above, there is considerable evidence of the rapid development of face processing expertise early in life (e.g., Bhatt et al., 2005), research suggests that body processing abilities are slower to develop (Heron & Slaughter, 2008; Slaughter & Heron, 2004; Slaughter, Heron & Sim, 2002). Slaughter and Heron (2004) concluded that body representation primarily develops during the second year of life, unlike knowledge about faces which is available quite early in life (Johnson, Dziurawiec, Ellis & Morton, 1991; Simion, Cassia, Turati & Valenza, 2001).

Slaughter and colleagues (2002) habituated infants to line drawings or photographs demonstrating various normal human body postures. Infants were tested on a series of scrambled body postures. Both 15- and 18-month-old infants showed a significant recovery of interest when presented with the scrambled bodies, demonstrating that they found the scrambled bodies to be novel compared to the intact bodies. In contrast, 12-month-olds failed to pick up on the violations to the human body. However, 12-month-olds discriminated scrambled *facial* features suggesting that 12-month-olds are sensitive to the relations among facial features but not body parts at this age. In a different study using an object examination task, 24-month-old infants discriminated between novel scrambled dolls and normal dolls across three violations to the body shape (i.e., arms on head doll, armless doll, and arms on hips doll), while 15- and 18-month-olds only noticed the “arms on head” violation (Heron & Slaughter, 2010). Based upon this and other studies, Slaughter and Heron (2004) generated a model of body knowledge development which assumes that infant’s knowledge about body features and holistic structure is slow to develop and that even rudimentary aspects of body information are not well developed until after 15 months of age.

Slaughter and Heron’s (2004) model of body knowledge may have underestimated the body-processing abilities of infants in the first year of life. For example, 4- to 6-month-old infants prefer to look at point-light displays of a human form exhibiting a pattern of biological motion versus a random pattern of moving dots (Fox & McDaniel, 1982). Infants’ preference for the human form remained when paired against the same biological motion just rotated 180 degrees. Additionally, Bertenthal, Proffitt and Cutting, (1984) found that 3-month olds can discriminate between upright and inverted human walkers in point-light motion displays. Bertenthal, Proffitt, Spetner, and Thomas (1985) tested infants to see whether this ability was innate or mediated by perceptual experience. They used point light displays which are readily recognized as human forms by adults when occlusion information (i.e. a cue for depth) is present, but not when it is absent or inconsistent with the structure of the human body. They found that 9-month-old infants, like adults, were sensitive to the presence of occlusion information in point-light walker displays. However, 7.5- and 5-month-old infants did not show any sensitivity to this information when occlusion was manipulated in the upright walker or scrambled walker conditions. These results support the notion that some sort of body representation may be present at least by 9 months of age.

More recent research by Christie and Slaughter (2010) suggests that infants do have body knowledge within the first year of life, but only under particular circumstances. They found that 9-month-olds had a preference for a normal body over a scrambled body when biological motion was included as an additional cue through animating the photographs. When live models moving their arms and head naturally were used in a visual habituation test, 4- to 6-month old infants showed an ability to discriminate between normal and physically impossible body positions (Slaughter et al., 2012). In addition, Morita and colleagues (2012) examined infants' eye movements during impossible and possible body movements. They found that 12-month-old infants, like adults, have knowledge of movement constraints within the context of a body, but 9-month-olds do not.

Furthermore, Zieber and colleagues (2010) found that infants in the first year of life are also sensitive to the relative proportion of body parts or body shape. Nine-month-olds looked longer towards distorted body images (e.g., long torso, short legs) than normally proportioned bodies, while 5-month-olds failed to demonstrate a preference. The fact that body knowledge is faster developing than predicted by Slaughter and Heron

(2004) is not surprising given that bodies and faces share several characteristics. However, the question remains as to whether infants process body information holistically. We examined this issue in the current study by testing whether infants' processing of body posture changes is holistic.

Chapter Two:

Experiment 1

In this study, we examined whether 3.5- and 9-month-old infants recognize changes in body posture. Body postures can be used much like facial expressions; for instance, posture can be used to share approval, insult, intention, or reenact an experience (Tomasello, Carpenter, Call, Behne & Moll, 2005). Body postures also signal whether a person is a friend or foe, whether that person is attending to us, and what actions one should take (Dael, Mortillaro & Scherer, 2012; de Gelder, 2006). Therefore, the ability to discriminate between various body postures can be a critical step in developing typical social skills.

Recall that some research has found that 9-month-old infants have greater body knowledge than predicted by Slaughter and Heron's (2004) model (e.g., Zieber et al., 2010). Therefore, it is possible that 9-month-olds will be sensitive to posture differences induced by changes in the positions of an arm and a leg. To examine developmental changes in body knowledge, we also tested a group of 3.5-month-olds. The decision to examine holistic body processing at 3.5 months of age was based on the youngest age at which holistic processing of faces has been shown (Turati, Di Giorgio, Bardi & Simion, 2010). At the same time, other research has shown that infants this age do not have well-developed body representations (Slaughter et al., 2012; Zieber et al., 2010). Therefore, the age range of 3.5 to 9 months might span a period of significant developmental change.

Method

Participants. The participants were 12 9-month-old infants (mean age = 279.8 days, *SD* = 7.42; 6 female) and 18 3.5-month-old infants (mean age = 103.1 days, *SD* = 9.23; 9 female). Infants were recruited through birth announcements and a local hospital. They were predominately Caucasian and from middle-class families. Data from 4 additional 3.5-month-old infants were excluded due to side bias (n = 3) and a failure to sample both test stimuli (n = 1).

Stimuli. Three pairs of stimuli were created. The stimuli were color, female figures created using Poser 2.0 software (Curious Labs, Santa Cruz, CA). Each figure’s arms and legs were positioned in such a way as to create novel poses (Figure 2.1). The poses were visually distinguishable from each other and could not be easily labeled. Each pose was physically possible. The second variation of each figure was constructed by altering the orientation of one arm and one leg of the figure (Figure 2.1). In total, six upright physically possible body postures were constructed using three different bodies, two body posture variations for each body. Changes in the orientation of the arm and leg were approximately the same across the three pairs.

Female bodies were used in this study because research suggests that infants prefer female faces to male faces and process female faces at a more specific level than male faces (e.g., Quinn, Yahr, Kuhn, Slater & Pasalis, 2002; Ramsey-Rennels, Langlois & Marti, 2005). In other words, infants exhibit a preference for females over males and also exhibit a greater degree of expertise on female stimuli. Therefore, female bodies could potentially induce infants to display greater knowledge about human bodies.

Apparatus. Infants were seated on their parent's lap approximately 45 cm in front of a 50-cm computer monitor in a darkened chamber. The parents wore opaque darkened glasses that prevented them from viewing the stimuli and were asked not to point or signal in any way to the infant during the procedure. A video camera located on top of the monitor was used to monitor and record infants' performance for later off-line coding.

Procedure. The present study utilized a familiarization-novelty preference procedure that has been used in several previous studies (e.g., Pascalis, de Haan & Nelson, 2002; Scott & Monesson, 2009). During familiarization, the infants were simultaneously exposed to two identical copies of the same body posture. The bodies remained on the screen until the infant accumulated 30 s of look duration to the stimuli. Immediately following the single familiarization trial, infants were tested on two 8 s test trials in which the familiar body posture was presented on one side while the same body, in a novel posture, was presented on the other side. Each trial was preceded by an attention-getter in which alternating green and purple shapes appeared in the center of the monitor. Infants were tested for their preference between the familiar and novel body posture. In studies using this kind of procedure, infants tend to look longer at the novel, unfamiliar image (Pascalis et al., 2002).

The left-right position of the novel body posture during the first test trial was counterbalanced across participants and reversed during the second test trial. A third of the infants at each age were tested on one of the three body pairs. In addition, the familiarization and test stimuli were counterbalanced within each age, so that both postures for each body served equally often as the familiarization and novel test stimuli. In other words, half of the infants were familiarized to a body pose and tested with the same body depicting a second pose as the novel stimulus while the other half of the infants were familiarized to the second pose and tested with the first pose as the novel stimulus.

Video coding was completed offline by a coder blinded to experimental condition and the left-right location of stimuli. The video was played back at 25% of the normal speed during coding. Data from 25% of the infants were coded by a second observer to establish reliability. The Pearson correlation between the two observers was .96.

As in prior studies (e.g., Bhatt et al., 2005; Scott & Monesson, 2009), the dependent measure was the percent preference for the novel body posture across the two test trials. This was calculated by dividing the total looking time toward the novel body posture across the two trials by the total looking time toward both the novel and familiar body postures across the two trials, and multiplying this ratio by 100.

Results and Discussion

The mean time required to accumulate 30 s of looking during familiarization for 3.5- and 9-month olds did not differ significantly (see Table 2.1), $t(1,20) = -.774$, $p = .45$. This implies that younger and older infants found the whole body stimuli equally engaging during familiarization.

An analysis of outlier status (Tukey, 1977; using SPSS version 20.0) revealed that the scores of two 9-month-old infants were outliers. The final analyses of test performance were conducted without these scores. Nine-month-old infants had a mean novelty preference score that was significantly above chance performance (50%), $t(9) =$

4.85, $p < .01$, see Table 2.1. This novelty preference is evidence of sensitivity to changes in body posture. In contrast, 3.5-month-olds had a mean novelty preference score that was not significantly different from chance performance (50%), $t(17) = -.207$, $p = .84$, indicating that they failed to process the body posture changes. A between-group *t*-test comparing 3.5- and 9-month olds performance revealed that 9-month-olds mean novelty preference score was significantly different than 3.5-month-olds mean novelty preference score, $t(1,26) = 2.32$, $p <.05$, d = .809. These results revealed a developmental change from 3.5 to 9 months of age in infants processing of body posture: older infants discriminated body posture changes but the younger infants did not. Given that older infants discriminated body posture changes, we proceeded to investigate whether their processing of this body information was holistic.

Table 2.1

Mean (and Standard Error) Percent Preference for the Novel Stimulus

	Condition	N	Mean Time to Habituate (s)	Mean Novelty Preference (%)	*t* (versus chance)
<u>Experiment 1:</u>					
9-month-olds	Whole Body	10	41.54 (3.92)	57.00 (1.44)	4.85*
3.5-month-olds	Whole Body	18	36.32 (4.52)	49.39 (2.94)	-.207
<u>Experiment 2:</u>					
9-month-olds	Parts	12	38.65 (2.80)	50.99 (2.56)	.386
	Scrambled	12	37.96 (2.38)	50.55 (1.94)	.282

* p <.001, significantly different from chance (50%).

Figure 2.1 Examples of the 'whole body' test stimuli in Experiment 1. In each condition, infants were initially familiarized to an image containing two identical body postures and then tested with the familiarization posture and a novel body posture. The novel posture was created by changing the orientation of an arm and a leg.

Familiarization Image:

Test Image:

Chapter Three:

Experiment 2

Evidence of holistic body processing in adults includes the finding that part discrimination is superior in the context of the whole body than when presented individually (Reed et al., 2006). In Experiment 2, we examined whether 9-month-olds also discriminate the change in positions of an arm and a leg better within the context of the whole body than in isolation. If infants discriminate changes in body posture in the context of the typical body but not in isolation, then it would indicate holistic processing (Reed et al., 2006; Tanaka & Farah, 1993).

Additionally, while infant's superior detection of changes to limb orientation in the context of the whole body rather than in isolation suggests holistic processing, this result may not necessarily indicate knowledge about bodies per se. Infants may be able to detect orientation changes as long as a sufficient context is provided, even if this context is not the typical body. In other words, infants' detection of limb orientation changes in Experiment 1 may not have been based on their knowledge about bodies, but rather based upon the presence of some context that anchored the limbs.

To examine this issue, an additional group of infants was tested with scrambled bodies. Scrambled bodies were used as the control because all parts of the normal, whole-body were present, albeit in a scrambled fashion (Figure 3.1). Scrambling preserves the low level-features of normal bodies including contrast and visual detail, and distorts only the configural properties, that is, the unique overall shape used to signify a human body as opposed to another object. If, despite the presence of all parts, infants fail to discriminate the same changes that they discriminated in the whole-body condition of

Experiment 1, then it would suggest that the holistic processing exhibited in Experiment 1 reflected body-specific processing (Reed et al., 2003; Reed et al., 2004; Seitz, 2002; Tanaka & Farah, 1993). Thus, in Experiment 2, two groups of 9-month-olds were tested, one with just the isolated parts and another with scrambled body parts.

Method

Participants. The participants were 24 9-month-olds (mean age = 271.38 days, *SD* = 8.46; 13 female). Infants were recruited in a similar manner as in Experiment 1.

Stimuli. Isolated body-part stimuli were created from the whole-body stimuli used in Experiment 1. Recall that the whole body posture changes involved only an arm and a leg. The isolated part stimuli were created by presenting only these parts and omitting the rest of the body (Figure 3.1). The isolated arm and leg parts remained in the exact locations they occupied in the whole-body condition. In other words, the pose changes depicted in the whole body stimuli were exactly duplicated in the body-part stimuli, except that just the parts that were involved in the pose changes were visible and the rest of the body was not presented (Figure 3.1).

Scrambled body stimuli were also created from the whole-body stimuli used in Experiment 1. The critical arm and leg whose orientations were changed in each stimulus were, once again, left in the same position; however, the remaining body parts (torso, arm, and leg) were moved to new locations and reattached (Figure 3.1). The non-critical parts (arm, leg, and torso) were placed in novel, physically impossible configurations. The position of the head was not altered, so that any effects of scrambling can be attributable to body part reorganization rather than to the displacement of the head.

Procedure. The procedure was the same as in Experiment 1, except that infants were tested with only parts or with scrambled bodies (Figure 3.1). The dependent measure was infants' percent preference for the novel posture across the two test trials. Counterbalancing and left-right location of test stimuli were done exactly as in Experiment 1. Coding of the infants' performance was conducted as in Experiment 1. Data from 25% of the infants was coded by a second observer to document reliability. The Pearson correlation between the two observers was .95.

Results and Discussion

The time required for infants to accumulate 30 s of look duration is presented in Table 2.1. There were no statistically significant differences in the time it took infants to accumulate 30 s of familiarization in the isolated parts compared to the whole body in Experiment 1, $t(1, 20) = .613$, $p = .55$, or the scrambled body compared to the whole body, $t(1, 20) = .810$, $p = 43$. Thus, there was no evidence to suggest differences in the pattern of familiarization to the three kinds of stimuli.

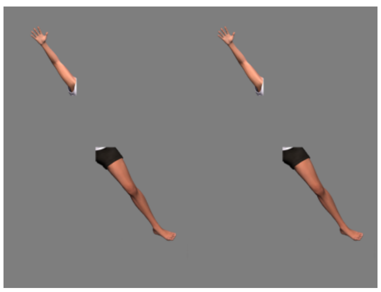
An outlier analysis, conducted as in Experiment 1, did not reveal any outliers in the isolated parts or scrambled body conditions. Thus, all infants' scores were included in the final analysis. The score of infants in the isolated part condition did not differ significantly from chance, $t(11) = .39$, $p = .71$, indicating the isolated part information was not enough to elicit discrimination. A between-group *t*-test comparing performance in the parts only condition of Experiment 2 with the whole body condition of Experiment 1 revealed that the mean novelty preference score in the whole body condition was marginally greater than the mean novelty preference score in the part condition, $t(1,20) = 1.94$, $p =.07$, d = .853. Thus, while 9-month-old infants discriminated changes to limb positions in the whole-body condition in Experiment 1, they failed to discriminate the same changes when only the critical parts were available. This indicates that infants' processing of body posture is holistic.

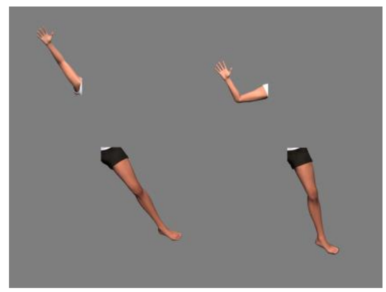
Infants in the scrambled body condition also failed to exhibit a looking preference that was significantly different from chance, $t(11) = .28$, $p = .78$, indicating that the addition of whole body information was not enough to elicit discrimination. A between-group *t*-test comparing performance in the scrambled condition of Experiment 2 with the whole body condition of Experiment 1 revealed that the mean novelty preference score in the whole body condition was significantly greater than the mean novelty preference score in the scrambled body condition, $t(1,20) = 2.56$, $p < .02$, d = 1.22. These findings indicate that 9-month-olds discriminated between changes in body posture in the whole body, but not the part or scrambled conditions. Thus, 9-month-old infants discriminated posture changes involving limb orientations only in the context of the intact human body in its typical configuration, indicating that they process human body posture holistically.

Figure 3.1. Examples of the ‘body part’ (A) and ‘scrambled body’ (B) test stimuli in Experiment 2. In each condition, infants were initially familiarized to an image containing two identical body postures and then tested with the familiarization posture and a novel body posture. The novel posture was created by changing the orientation of an arm and a leg.

Familiarization Image: Test Image:

A.





B.

Chapter 4:

General Discussion

Nine-month old infants discriminated changes in the orientation of limbs within the context of a typical whole body, but failed to detect the same changes when body parts were presented in isolation or in the context of scrambled bodies. Thus, 9-month-olds exhibited evidence of holistic processing of body information. However, 3.5-month-olds failed to discriminate between whole body postures and therefore no conclusion can be made about their ability to use holistic strategies to process bodies. These results indicate that, contrary to some prior conclusions about the late development of body knowledge (Slaughter & Heron, 2004; Slaughter et al., 2002), holistic processing of bodies is evident by at least 9 months of age, although its developmental origin is unknown.

The fact that discrimination by older infants was evident only in the whole body condition suggests that by 9 months of age infants' representation of the human body includes information about the relative configuration among body parts. The lack of discrimination in the isolated parts condition indicates a disruption in the processing of body posture information in the absence of the whole body context, which is an indication of holistic expert processing. It could be argued that infants failed to discriminate in the part condition simply because of a lack of sufficient information. That is, without the presence of other features as spatial anchors for comparison and contrast, it may have been difficult for 9-month-olds to process the changes in the orientation of the limbs. However, infants' failure to discriminate in the scrambled body condition in Experiment 2 argues against this possibility. Scrambled bodies served as effective control stimuli because all of the information that was present in the intact whole body was also present in the scrambled body, although in a scrambled fashion that would not elicit body-specific processing mechanisms. Moreover, the scrambling did not interfere with the position of the critical limbs involved in the posture changes. Nevertheless, the fact that 9-month-olds failed to discriminate posture changes in the scrambled images indicates that they discriminate changes in the orientation of limbs more readily in the context of the canonical structure of the body. Therefore, like adults, 9-month-olds have developed an expertise with bodies that is analogous to face-processing expertise: with both categories of stimuli, infants this age exhibit evidence of holistic image processing.

It is also possible to use inverted bodies as control stimuli when investigating body knowledge and holistic processing (Reed et al., 2003; Seitz, 2002); however, the inversion effect (i.e., poorer performance on inverted bodies) is not always found in the adult literature on faces and bodies (Leder & Bruce, 2000; Yovel, Pelc, & Lubetzky, 2010). Moreover, inversion would disrupt the locations of the head and the critical arm and leg whose orientation were changed. Thus, inversion was not used as the control stimuli in the current study.

The present findings indicate that, in the first year of life, body knowledge is more detailed than predicted by Slaughter and Heron’s (2004) model, which posits that detailed knowledge about bodies develops only in the second year of life. One explanation for this may be that the Slaughter studies used successive discrimination procedures, in which one test image is viewed at a time, while the current study used a paired-comparison procedure in which infants were tested with novel and familiar stimuli presented side by side. Previous research shows that paired-comparison procedures can be more sensitive because they are less taxing on memory processes (Eimas, Quinn, & Cowan, 1994; Quinn, 1987; Reznick & Kagan, 1983; Younger & Furrer, 2003). Additionally, in contrast to the female bodies used in the current study, the original studies by Slaughter and colleagues used images of male bodies. The face literature suggests that infants may be more expert on female bodies because infants prefer to look at female faces and also process female faces at a more specific level than male faces (Quinn et al., 2002; Ramsey-Rennels et al., 2005). The use of female images in the current study may have thus facilitated infants' performance.

The current finding that 9-month-olds process body information holistically is consistent with other research on the development of body processing that indicates earlier development of body knowledge than envisioned by the Slaughter and Heron (2004) model (Christie & Slaughter, 2010; Slaughter et al., 2012; Zieber et al., 2010; Zieber, Kangas, Hock & Bhatt, in press). As discussed in the Introduction, Bertenthal and colleagues (1984) have shown that infants as young as 3 months of age can recognize the biological motion of humans in point-light displays (Bertenthal et al., 1984; Fox & McDaniel, 1982). Furthermore, 8-month-old infants' ERP responses differ between intact versus scrambled point-light displays of human body movement, as well as between upright and inverted point-light displays (Hirai & Hiraki, 2005). Additionally, Gliga and Dehaene-Lambertz (2005) found differences in ERP responses between intact versus part-reorganized body stimuli at just 3 months of age. Finally, 6.5-month-olds are sensitive to body emotions portrayed in dynamic displays (Zieber et al., in press). They prefer to look at emotional actions compared to neutral actions. Infants also discriminate between happy and angry emotional videos and match emotional videos to appropriate affective vocalization (Zieber et al., in press). Taken together, the aforementioned research indicates some kinds of body knowledge are available within the first year of life.

The finding that 9-month-olds process body posture holistically extends previous research on holistic face processing in infancy to bodies. Recall that holistic processing is a mark of expertise, which presumably enables infants and adults to process information efficiently and effectively. Additionally, research shows infants more readily respond to configural information in faces than in non-face stimuli, demonstrating specialization on faces (Zieber et al., 2013). However, the extent of specialization of infants' knowledge about bodies is unclear. Heron-Delaney, Wirth and Pascalis (2011) showed that 3.5-month-olds prefer to look at a human body when compared with a non-human (primate) body indicating infants can recognize the human form. It would be interesting to investigate whether 9-month-olds' holistic processing of posture information is confined to humans or extends to non-human animals.

In contrast to 9-month-olds, 3.5-month-olds in the current study failed to discriminate between whole body postures, indicating a developmental change between these ages. One possible explanation for the developmental difference is that young infants have not attained the degree of visual experience that is required to process body posture. Young infants have difficulty holding an upright posture and consequently most often interact with a caregiver in their typical supine position. As a result, these infants are occasionally shielded from viewing caregiver's entire body (Stern, 2009). Consequently, young infants may not have had sufficient experience with bodies to engage in holistic processing. Additionally, work by Slaughter and colleagues (2010) suggests that younger infants' discrimination performance is more stimulus dependent than that of older infants. Therefore, it is possible that infants at 3.5 months of age do have knowledge about body posture, but the procedure and stimuli used in the current study were not able to demonstrate this ability. Perhaps 3.5-month-olds would discriminate between whole body postures if they are given more time during familiarization (Colombo, Mitchell, Coldren & Freeseman, 1991; Hunter, Ames & Koopman, 1983; Pascalis & de Haan, 2003). Similarly, younger infants might discriminate if the degree of change from one pose to another was greater, thereby increasing the difference between test stimuli.

In summary, the current research is consistent with previous evidence (Gliga & Dehaene-Lambertz, 2005; Heron et al., 2011; Zieber et al., 2010) indicating a fairly high level of body knowledge during the first year of life. The findings indicate that 9 months of experience is sufficient for infants to develop enough expertise with bodies to prompt holistic processing. To our knowledge, the current study is the first to indicate that 9-month-olds use holistic information to discriminate human body postures. The presence of a developmental change between 3.5 and 9 months of age implies that body knowledge is rapidly developing during the first year of life and one goal of future research should be to pursue the precise developmental origin of holistic body processing, presumably sometime before 9 months of age.

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